TRB PAPER NUMBER 981579: THE EMISSIONS REDUCTION POTENTIAL OF THE CONGESTION MITIGATION AND AIR QUALITY IMPROVEMENT (CMAQ) PROGRAM: A PRELIMINARY ASSESSMENT

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The Emissions Reduction Potential of the Congestion Mitigation and Air Quality Improvement (CMAQ) Program: A Preliminary Assessment

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ABSTRACT

The Congestion Mitigation Air Quality (CMAQ) program provides funds to states for projects designed to help attain the national ambient air quality standards (NAAQS). However, to date there has been no attempt to quantify the national emissions effects of the CMAQ program or its potential.

States are requested to provide to FHWA estimates of emissions reductions associated with projects funded by CMAQ. These reports provide a rich source of data for analysis of the CMAQ program, although the data have various limitations. This paper develops a methodology to estimate potential impacts of the CMAQ program on emissions of volatile organic compounds (VOC), oxides of nitrogen (NO_X) and carbon monoxide (CO), using data provided by the states to FHWA.

Using this methodology, this paper provides a preliminary assessment of the emissions effect of the CMAQ program from its inception in 1992 through 2005. It suggests that the CMAQ program is playing a significant role in reducing emissions nationwide. Emissions estimates are sensitive to assumptions about project cost-effectiveness and years of effect. In addition, this paper notes various limitations in the national database of CMAQ projects. It recommends the use of consistent methodologies for estimating the effects of programs nationwide to improve the accuracy of national emission reduction estimates.

Key words: emissions, air quality, transportation control measures (TCMs)

INTRODUCTION

The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 established the Congestion Mitigation and Air Quality Program (CMAQ) as a tool to help states and localities improve air quality through transportation programs. CMAQ provides funds to states for projects designed to help attain and maintain the national ambient air quality standards (NAAQS). Projects eligible for CMAQ funding include measures listed in the Clean Air Act Amendments (CAAA) as transportation control measures (TCMs), transit improvements, and inspection and maintenance (I&M) programs. They are classified under six categories *(1)*:

- traffic flow improvements (e.g., signalization improvements; traffic management/control, such as incident management and ramp metering; and improvements at intersections)
- transit improvements (e.g., system/service expansion, replacement of buses with cleaner vehicles, and market strategies)
- shared ride services (e.g., park-and-ride facilities, the establishment of vanpool or carpool programs, and programs to match drivers and riders)
- demand management strategies (e.g., promotion of employee trip reduction programs and development of transportation management plans)
- bicycle and pedestrian (e.g., development of bicycle trails, storage facilities, and pedestrian walkways, as well as promotional activities)
- inspection and maintenance (I&M) and other (e.g., updating inspection and maintenance quality assurance software and training, construction of advanced diagnostic facilities or equipment purchases, conversion of public fleets to alternative fueled vehicles, and other projects)

Eligibility was expanded in 1995 to include outreach activities, experimental pilot projects/innovative financing, and fare/fee subsidy programs *(2)*.

Projects funded by the CMAQ program are designed to reduce emissions from motor vehicles. However, there has not been an attempt to quantify the emissions effects of this program nationally or to assess potential emissions reductions in the near future. Various methodologies have been developed to assess the emissions effects of individual transportation control measures (TCMs) and other programs targeted at motor vehicle emissions reductions *(3)*. However these methods are not geared toward national analysis or the wide variety of projects eligible for CMAQ funding.

Each year, all states receiving CMAQ funds are requested to provide to FHWA emissions reduction estimates associated with CMAQ projects. These reports provide a rich source of data for analysis of the CMAQ program. However, the data have various limitations since there are no requirements for consistent use of emissions estimation methodologies.

This report develops a procedure to quantify the potential of the CMAQ program to reduce emissions of volatile organic compounds (VOC), oxides of nitrogen (NO_X), and carbon monoxide (CO) in the U.S., using data provided by the states to FHWA in FY 1994 *(4)*. This study examines various approaches to this task, as well as fundamental assumptions necessary to predict emissions effects into the future and limitations in data submitted by the states. It develops an approach that addresses various data concerns.

Using this methodology, this study develops estimates of the CMAQ program's cumulative effect on emissions, from the program's inception in 1992 through 2005. It concludes that the program could result in significant reductions in air pollutant emissions. It also highlights the need for emissions estimation methodologies to be applied consistently across the states in order to improve the accuracy of predictions about CMAQ's effect.

METHODS FOR ESTIMATING IMPACTS

One could attempt to estimate the potential effectiveness of the CMAQ program in several ways. Various methods were considered for this study.

Trend-line Forecast

A very simple approach to estimating emissions impacts would be to sum the reductions reported to FHWA by the states for each project to obtain a national total for each year. The national total from each year could then be used to develop an average emissions effect per year or trend-line effect to estimate program emission reductions in the near future.

However, such an approach has five weaknesses for estimating the potential effectiveness of the program into the future.

1. No emissions estimates are reported for a number of projects. About 77 percent of CMAQ projects reported quantified emissions reductions in FY 1994. The percentage of projects reporting quantified emissions reductions has increased each year, from 28 percent of projects in FY 1992 and 69 percent of projects in FY 1993 *(5 and 6)*. A lack of quantified emissions estimates for some projects does not mean that these projects did not have any effect on emissions. Metropolitan planning organizations (MPOs) performing the analyses may not have had the appropriate methodologies to estimate effects from certain types of projects. A trend-line approach might capture changes in emissions effects due to improved reporting rather than actual increases in emissions effects.
2. If the effects of all reported projects are summed to develop an estimate of nationwide effects, the national total is dependent upon each data point provided by each state. As a result, any misreported figure or poor methodological assumptions used in any state analysis could skew the national results. Similarly, emission estimates from a few large projects, which may not be representative of typical CMAQ projects, could skew projections.
3. Obligation levels have differed from year to year, and funding is projected to increase in the future under NEXTEA, so this approach would not allow one to examine potential effects under predictable changes in funding levels.
4. Most projects produce benefits over several years, and these project lifetimes vary. This approach does not provide a clear method to assess the cumulative effects of multiple years of spending on emissions.
5. The cost-effectiveness of CMAQ projects might increase as states and localities become more familiar with the CMAQ program and more effective at targeting limited program funds.

Case Study Approach

A second approach would use case studies of projects that cities and states have funded with CMAQ to estimate an average cost effectiveness per project. Projections of future CMAQ expenditures (in dollars) could then be divided by the project cost-effectiveness estimates (in dollars per kg of reduction) to yield kg of emissions reduced. However, pre-selecting individual projects or case studies for application to the national level is fraught with uncertainty and the potential for bias since the selected projects may or may not be representative of most projects. In addition, any estimated improvements in project effectiveness over time would be arbitrary. Such an approach fails to utilize the rich database of CMAQ projects from across the nation.

Selected Approach

To avoid the weaknesses of the straight-line forecast and the case study approach, this study developed a methodology for emissions estimation that involves developing an estimate for the cost-effectiveness of CMAQ projects in the future based on the full database of FY 1994 CMAQ projects. These cost-effectiveness figures represent dollars of federal CMAQ obligations per ton of pollutant reported reduced, and do not correspond with cost-effectiveness figures that include all project costs and project effects over the life of the project. Separate cost-effectiveness estimates were developed for each pollutant. Possible future CMAQ expenditures were then divided by project cost-effectiveness to yield an estimate of kg of emissions reduced.

Most CMAQ projects produce emission reductions over multiple years, and different types of projects produce benefits over different numbers of years. For example, transit projects, which often involve bus replacement, might produce fewer years of effect than bicycle and pedestrian infrastructure projects. Since years of emission effects were expected to differ for different categories of projects, projects were grouped into categories and “life-time” assumptions were developed for each category. Cumulative emissions reductions for each analysis year are the sum of the emissions reductions from project spending over prior years.

The methodology for estimating the reductions in emissions of each pollutant involved four steps:

1. Estimate Obligations

The President’s reauthorization proposal for ISTEA (referred to as NEXTEA) proposed $1.3 billion in annual CMAQ authorizations. This analysis assumed that $1.047 billion of this would be obligated annually for FY 1998-2003 based on information from the Office of Management and Budget. Table 1 provides annual obligation rates used in the analysis. These obligation figures were then converted into 1994 dollars.

CMAQ expenditures were assumed to be spent in project categories according to the proportion of spending on each project category in FY 1994, as shown in Table 2. About 9 percent of funds (STP/CMAQ funds) are distributed to states without any non-attainment areas. This analysis used the conservative assumption that CMAQ spending in states without any non-attainment areas does not result in emissions reductions. Although the proportion of projects in each category will likely change somewhat over time, this analysis uses the conservative assumption that there will be no shifts in funding to more effective categories of spending.

2. Estimate Future Cost-Effectiveness for Each Project Category

For each project category, a cost-effectiveness estimate was calculated to represent the average cost-effectiveness of projects in the future. The first method examined was simply to use the average cost-effectiveness based on all project spending and emission effects reported for each category in FY 1994. However, the nature of the data made use of this method problematic.

A few projects reported extremely high emissions reductions. For example, one project reported over half of all the VOC emission reductions reported nationwide. Since the projects did not exhibit a normal distribution, the extremely high emissions reductions reported for a handful of projects pushed the average emissions reduction per dollar higher than the level exhibited by most projects. See Table 3.

The estimated tons of pollution reduced per project were highly skewed, as were dollars per ton reduced, as shown in Figure 1

As a result of very high emission estimates for a small number of projects, the average reduction per dollar was extremely dependent on a few project reports, whose validity we could not check. FHWA did, however, do some screening of reported emissions effects and eliminated some emissions reports from the database *(4)*. An alternative approach to estimate cost-effectiveness for projection purposes was to use the median cost-effectiveness of projects within a category.

In order to determine the median, projects in each project category were ranked from highest to lowest cost-effectiveness in separate analyses for each pollutant. Cost-effectiveness was calculated by dividing reported emissions reductions for each pollutant by federal CMAQ project expenditures. Projects with no reported emissions reductions (including those with emissions increases) were not placed in these rankings since it would not be appropriate to assume that no emissions reductions occur for projects that do not report any emissions benefits. These projects may have been located in areas that were in attainment for the non-reported pollutant. Projects that resulted in increased emissions were dropped from the analysis since negative cost-effectiveness values are not meaningful in this context.

Since the CMAQ database presented emissions reductions in kg/day, daily reductions were multiplied by 240 days per year to calculate annual reductions, assuming most projects affect workweek travel. This assumption is conservative (i.e., tends to underestimate emissions reductions) since many projects—such as enhanced inspection and maintenance (I&M) programs and traffic flow improvements—affect travel and/or emissions every day.

The cost-effectiveness of the median (50^{th} percentile) project was then selected within each project category. The cost-effectiveness of the 60^{th} percentile project was selected to represent possible future cost-effectiveness. Use of the 60^{th} percentile was selected rather than an arbitrary percentage increase in cost-effectiveness over the median cost-effectiveness. The cost-effectiveness of the 60^{th} percentile project was judged to represent a potential level of improvement since 40 percent of projects already reported higher cost-effectiveness than this level. Enough data were available to rank projects in terms of cost-effectiveness at reducing VOC, CO, and NO_X. Particulate matter (PM) was not included in the analysis since too few projects reported PM emission reductions to perform meaningful statistical analysis. See Table 4.

3. Calculate emissions effects from each year of spending

The annual CMAQ obligations for each category of projects were divided by the cost-effectiveness for each project category (computed in Step 2) to develop a range of estimates for tons of pollutants reduced nationally. These figures represent emission reductions associated with each year of spending on CMAQ.

4. Calculate cumulative effects

To calculate the cumulative effects of the CMAQ program, lifetimes for project impacts were estimated based on a methodology developed by California's Department of Transportation and the California Air Resources Board for estimating emissions effects of CMAQ projects *(7):*

- Traffic flow improvements: 12.5 years (average of recommended range, 5 to 20 years)
- Transit: 12.5 years (average of 5 years for replacement of old buses and 20 years for new service)
- Shared ride: 14 years (average of 8 years for vanpools/shuttles and 20 years for carpool park-and-ride lots)

- Demand management: 12.5 years (average of recommended range, 5 to 20 years)
- Bicycle and Pedestrian: 20 years (recommended value in California methodology)
- I/M and Other: 5 years (not estimated in the California methodology)

Throughout this analysis, spending was assumed to have a two year lagged effect on emissions. For example, I&M spending in FY 1994 would show an emissions effect in the years 1996 to 2000. Shared ride spending in FY 1994 would meanwhile show an emissions effect from 1996 through the end of the analysis period in 2005.

It is also important to note that some projects require more than a single year of CMAQ funding to achieve the reported benefits. That is, the emissions reductions a state reported for a single expenditure really anticipated further funding. If the FHWA database contained many such projects, then our methodology would over-estimate emission reductions. To assess the magnitude of this potential problem, we reviewed 3 years of CMAQ project data from Pennsylvania and California. While 9 percent of the Pennsylvania project were funded over multiple years, they only accounted for 2.7 percent of reported emission reductions. California's multi-year funded projects accounted for 2.5 percent of the state's reported emission reductions. To adjust for multi-year funding, we reduced total emission estimates for each year by 2.5 percent. See Tables 5a - 5b for yearly estimates.

CONCLUSIONS

This analysis produced four conclusions:

1. In 1999, the ISTEA CMAQ program is projected to reduce VOC emissions by about 47,300 metric tons (52,100 short tons), CO emissions by 305,100 metric tons (336,300 short tons), and NO_x emissions by 56,600 metric tons (62,400 short tons) (Tables 5a-5b and Figures 2a-c). In 2005, under NEXTEA, annual CMAQ emission reductions could grow substantially to between 94,500 and 149,800 metric tons (104,200 to 165,200 short tons) of VOC, 619,200 to 776,700 metric tons (682,500 to 856,200 short tons) of CO, and 98,900 to 250,200 metric tons (109,000 to 275,800 tons) of NO_x. These estimates represent the cumulative reductions from CMAQ projects funded through 1997 and 2003, respectively. The upper bound for projects funded after 1997 assumes that projects achieve improved effectiveness compared to projects funded prior to 1997.
2. Under NEXTEA, the projected emission reductions from CMAQ increase as emissions effects from prior years add to the effects of new funding. This increase occurs both absolutely, and relative to other CAA measures. For example, in 2005, CAA requirements for on-road vehicles will have reduced VOC emissions by approximately 806,000 metric tons (888,000 short tons), while CMAQ is projected to reduce VOC emissions by 94,500 to 149,800 metric tons (104,200 to 165,200 short tons). The emissions reductions associated with CAA requirements for on-road vehicles were calculated from projections in EPA's National Emissions Inventory Report *(8)*. While NEXTEA provides funding through 2003, emission reductions are estimated to 2005 since this is when projects funded in 2003 are expected to first produce results.
3. While increasing VMT threatens to reverse air quality gains made through ISTEA programs and through cleaner cars and cleaner fuels, Figure 3 suggests that CMAQ may help keep emission trends moving downward. Figure 3 illustrates EPA's estimates of emission trends from on-road vehicles with and without CMAQ *(8)*.
4. The estimated emissions reductions are sensitive to assumptions about the cost-effectiveness of projects. There is a large range in the estimated cost-effectiveness of CMAQ projects funded in FY 1994. In addition, emission reduction estimates are sensitive to the estimated years of effects associated with each project category. Fewer years of project effects would cause the emission reductions to reach a steady-state and plateau earlier. However, alternative project life assumptions would not have any effect on the first few years of cumulative impacts, only on later years if it is assumed that early years of project spending no longer continue to have an effect.

Overall, this study suggests that CMAQ is playing a significant role in U.S. emissions reduction, and could play an even larger role as funding continues.

Caveats and Additional Research Needs

This analysis provides an initial assessment of potential emissions effects from CMAQ projects. The methodology presented in this paper attempts to deal with various problems with CMAQ data. However, it is important to note a number of significant caveats, which suggest additional research needs to improve this type of this analysis:

Accuracy of reported emissions estimates is uncertain.

Emissions estimates associated with CMAQ spending are reported by individual states. Since Federal guidance neither imposes nor suggests a uniform approach, each state performs air quality analyses using its own methods, which may or may not include quality control or quality assurance mechanisms. Analyses use different underlying assumptions, emissions estimation methodologies, and types of data. FHWA has noted in the national database that occasionally numbers were reported that appeared unreasonable and required extensive follow-up. In some cases, it was not possible to obtain better information, and these figures were deleted by FHWA from their database. However, some states, such as California and Pennsylvania, have either suggested or used uniform evaluation methodologies. It is not clear to what extent, if at all, the states have taken into account the secondary effects of projects. For example, it is possible that traffic flow improvements that reduce travel times could lead to induced travel that would reduce emissions effectiveness.

This analysis deals with uncertainties in estimating CMAQ effects by performing statistical analysis using the entire database of projects, rather than pre-selecting an individual project or case study for analysis, which may or may not be representative of most projects. This analysis also uses a range of estimates in order to deal with the uncertainty in individual estimates. However, greater consistency in methodologies and stronger quality control mechanisms would improve confidence in the results.

Some projects report no emissions estimates.

About 77 percent of all CMAQ projects in FY 1994 reported quantified emissions reductions. Many of these projects reported emissions reductions for fewer than all four pollutants (VOC was the pollutant reported most often). Projects with no reported data for individual pollutants were dropped from the ranking of projects when selecting the 50^{th} and 60^{th} percentile projects within each category. Dropping these projects may have eliminated some projects with small impacts and raised the cost-effectiveness of the 50^{th} and 60^{th} percentile projects. However, it would not be appropriate to assume that no emissions reductions occur for projects that do not report emissions benefits. These projects may have been located in areas that were in attainment for the non-reported pollutant and did not feel it necessary to estimate impacts, or appropriate methodologies may have been unavailable. Non-attainment areas would be expected to target funding to projects that help them reach attainment status.

Nine percent of CMAQ funds were spent by states that did not have any non-attainment areas. This analysis uses the conservative assumption that CMAQ spending in states without any non-attainment areas does not result in emissions reductions. This assumption tends to underestimate CMAQ's effectiveness.

Timing of emission reductions is unclear.

CMAQ projects produce many different benefits, over different periods (these effects include non-air quality and emission benefits, such as congestion reduction). Some projects produce multiple-year emissions impacts (e.g., replacing transit buses with cleaner ones, developing bicycle facilities, and improving signalization) while other effects last only as long as funding lasts (e.g., any operating costs). For some projects, it may take many years to reach full benefits while for others the effect may occur immediately. FHWA's project database does not provide information on the duration of benefits or peak year for benefits. This analysis deals with this issue by making plausible simplifying assumptions about the number of years that a project may show emissions reductions, and by assuming that projects would need 2 years to have an emissions effect.

One alternative was to avoid the entire length-of-benefits issue and assume only one-year effects for each project. However, this approach clearly underestimates total emissions reductions since many projects from prior years will continue to have emissions effects for multiple years. On the other hand, any one assumption of multiple-year effects risks overestimating emission effects somewhat. FHWA suggests that air quality analysis be done for the year when the implemented project is expected to realize its maximum benefits. Some projects may require multiple years in order to reach full impact, in which case there will be some interim years in which the impact of spending is small. For example, CMAQ funding has been used to help establish Transportation Management Organizations, which may not yield reported impacts for a number of years. The maximum benefits of every project will not occur in the same year (i.e., some projects funded in 1999 may achieve maximum benefits in 2001, while others might achieve full emission reductions in 2004). However, our simplified analysis assumes that the reported (maximum) emission reductions occur each year during the timeframe of project effectiveness. As a result, the total emissions benefits estimated using the assumption of multiple year impacts may overstate the total benefits that would occur.

Cost-effectiveness of CMAQ projects in the future is uncertain.

Estimates of future cost effectiveness for emissions programs face several uncertainties. On the one hand, the cost-effectiveness of a particular type of project may fall in the future since each vehicle mile of travel (VMT) reduced will result in fewer grams of pollution reduced (since the average vehicle on the road will be cleaner, and emit less pollution per mile traveled). On the other hand, each dollar spent may produce more benefits since projected increases in travel and congestion nationwide may mean that a particular project reduces more VMT. This analysis estimated the potential of the CMAQ program using the cost-effectiveness of the 50^{th} and 60^{th} percentile of projects in FY 1994. Using the 60^{th} percentile cost-effectiveness figures to represent potential improvements in project cost effectiveness is supported by analysis of California and Pennsylvania data over multiple years. Analysis of these state reports finds that projects reported higher emission reductions per dollar of CMAQ funds obligated in 1996 compared to 1993. The assumption is that as the program continues, states will become more effective at targeting CMAQ funding, so projects are likely to have higher than the median 1994 cost-effectiveness in future years.

This analysis is conservative in that it assumes spending will continue to be apportioned among the six categories of CMAQ projects in the same manner as in 1994. That is, this analysis does not assume that funding shifts to the more cost-effective *categories* of projects, only to more cost-effective projects within each category. The assumptions used on this issue tend to underestimate potential effectiveness.

Costs measured in this analysis only account for Federal expenditures on CMAQ.

For most CMAQ-funded projects, federal CMAQ funds are only a portion of total project costs. As a result, the cost-effectiveness estimates used in this analysis should not be confused with cost-effectiveness estimates that include total costs. CMAQ projects often have substantial state and other funding sources. For example, $1.9 million in CMAQ funds contributed to total project costs of $6.4 million for a Freeway Service Patrol (to clear highway incidents) in San Francisco. CMAQ contributed

$7.3 million out of $13.7 million in total project costs to build an elevated pedestrian walkway connecting Tower City Center transit station to the Gateway Sports and Entertainment Complex in Cleveland. In other cases, CMAQ funds paid for most or all of project costs. For example, CMAQ provided $1.7 million out of $2.2 million for a transit operating assistance project in Ventura County, CA *(8)*. Some projects have financial costs for the private sector as well.

The cost-effectiveness figures used in this analysis should not be compared with estimates that do include all costs. This analysis assumes that the CMAQ program leverages other funds that would not have otherwise been spent on these projects. That is, if CMAQ spending were reduced, the states would not spend money on these projects. Thus, the full benefits of the projects are attributed to the CMAQ spending.

Project effectiveness varies by pollutant.

This analysis estimated potential effectiveness based on individual analyses of the median and 60th-percentile projects for each pollutant. In reality, a project that is near the top in cost-effectiveness for one pollutant may be average or near the bottom in cost-effectiveness for another pollutant. Metropolitan areas would be expected to target funding priority to projects that help them meet attainment status. As a result, regions may select projects that most cost-effectively reduce pollutants of their concern. However, at the national level, it may not be possible to achieve the full potential of CMAQ reported for all pollutants. Targeting projects that are highly effective in reducing one pollutant often results in less effectiveness at targeting the others. For example, 33 CMAQ-funded projects in FY 1994 that were reported to reduce VOC and CO were expected to result in *increased* emissions of NO_X. This is true for several traffic flow improvement projects, since emission models suggest that increasing travel speeds often reduces VOC and CO, but increases NO_X emissions. These findings stress the importance of examining CMAQ from a regional perspective—since regions can target funding to help implement their transportation/air quality plans—rather than solely from a national emissions inventory perspective.

Acknowledgements

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TABLE 1: CMAQ OBLIGATIONS (MILLIONS OF DOLLARS)

FY 1992—Actual	FY 1993—Actual	FY 1994—Actual	FY 1995—Actual	FY 1996—Actual	FY 1997—Actual
340	601	815	950	939	878
FY 1998—Estimate	**FY 1999—Estimate**	**FY 2000—Estimate**	**FY 2001—Estimate**	**FY 2002—Estimate**	**FY 2003—Estimate**
1047	1047	1047	1047	1047	1047

TABLE 2: PERCENT OF CMAQ OBLIGATIONS IN EACH PROJECT CATEGORY (FY 1994)

Traffic flow improvements	34
Transit	40
Shared ride	4
Demand management	5
Bicycle and pedestrian	2
I&M and other	6
STP/CMAQ	9

TABLE 3: PERCENT OF REPORTED EMISSION REDUCTIONS ASSOCIATED WITH TOP PROJECTS (FY 1994)

	VOC	CO	NO_X
Top one project	52	19	13
Top 1 percent of projects	80	38	30
Top 5 percent of projects	92	73	82

TABLE 4: NUMBER OF PROJECTS REPORTING EMISSIONS REDUCTIONS (FY 1994)

Project Type	VOC	CO	NO_X	PM
Traffic Flow	247	143	136	8
Transit	130	81	88	14
Shared Ride	81	30	51	5
Demand Mgmt	48	31	41	3
Bike/Pedestrian	60	43	42	5
I/M and Other	22	11	19	7

Table 5a: Estimated Cumulative Emission Reductions from CMAQ (thousands of metric tons)

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Volatile Organic Compounds (VOC)												
Lower Bound	3.9	10.5	19.4	29.4	39.2	47.3	56.3	64.6	72.4	80.0	87.5	94.5
Upper Bound	3.9	10.5	19.4	29.4	39.2	47.3	67.4	86.5	104.8	122.6	140.1	149.8
Carbon Monoxide (CO)												
Lower Bound	24.9	67.8	124.6	189.4	252.2	305.1	364.3	419.4	471.3	522.1	572.2	619.2
Upper Bound	24.9	67.8	124.6	189.4	252.2	305.1	392.3	474.6	553.2	629.9	705.2	776.7
Oxides of Nitrogen (NOX)												
Lower Bound	4.7	12.8	23.6	35.9	47.8	56.6	65.7	73.4	80.0	86.6	93.2	98.9
Upper Bound	4.7	12.8	23.6	35.9	47.8	56.6	97.6	136.3	173.2	209.2	244.6	250.2

Table 5b: Estimated Cumulative Emission Reductions from CMAQ (thousands of short tons)

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Volatile Organic Compounds (VOC)												
Lower Bound	4.3	11.6	21.3	32.4	43.2	52.1	62.1	71.2	79.8	88.2	96.5	104.2
Upper Bound	4.3	11.6	21.3	32.4	43.2	52.1	74.3	95.3	115.5	135.2	154.5	165.2
Carbon Monoxide (CO)												
Lower Bound	27.4	74.7	137.3	208.8	278.0	336.3	401.6	462.3	519.6	575.5	630.7	682.5
Upper Bound	27.4	74.7	137.3	208.8	278.0	336.3	432.4	523.2	609.8	694.3	777.4	856.2
Oxides of Nitrogen (NOX)												
Lower Bound	5.2	14.2	26.0	39.6	52.7	62.4	72.4	80.9	88.2	95.4	102.8	109.0
Upper Bound	5.2	14.2	26.0	39.6	52.7	62.4	107.6	150.2	190.9	230.6	269.7	275.8

FIGURE 1: REPORTED VOC EMISSION REDUCTIONS (FY 1994)

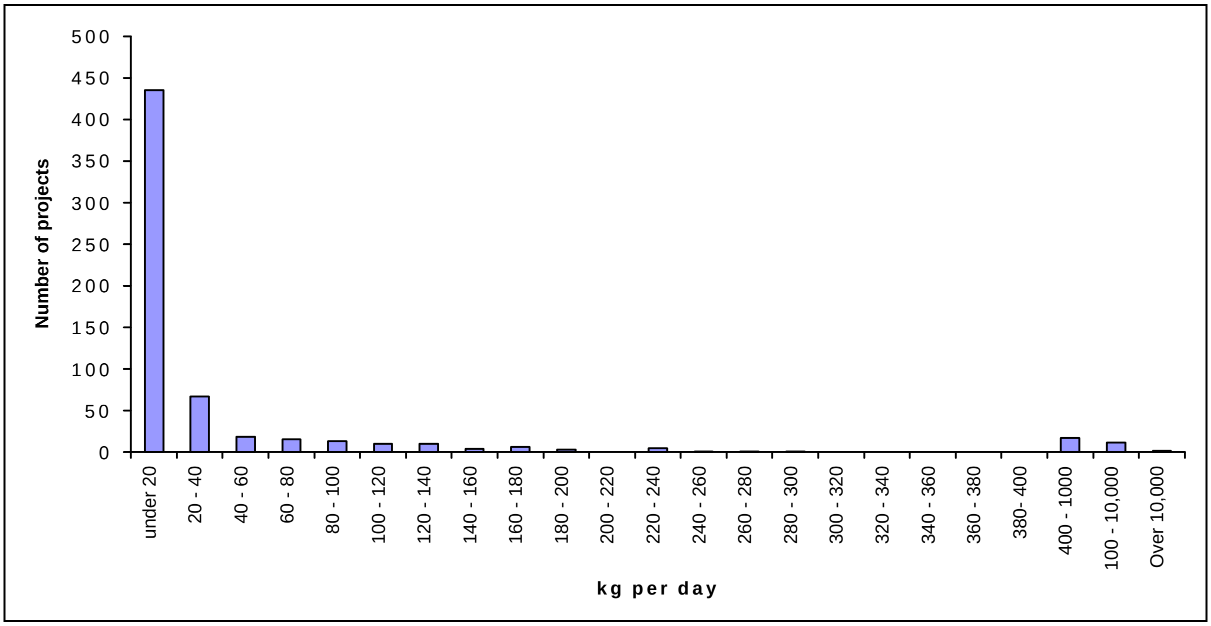


FIGURE 2A: ESTIMATED ON-ROAD VEHICLE VOC EMISSION REDUCTIONS FROM CMAQ

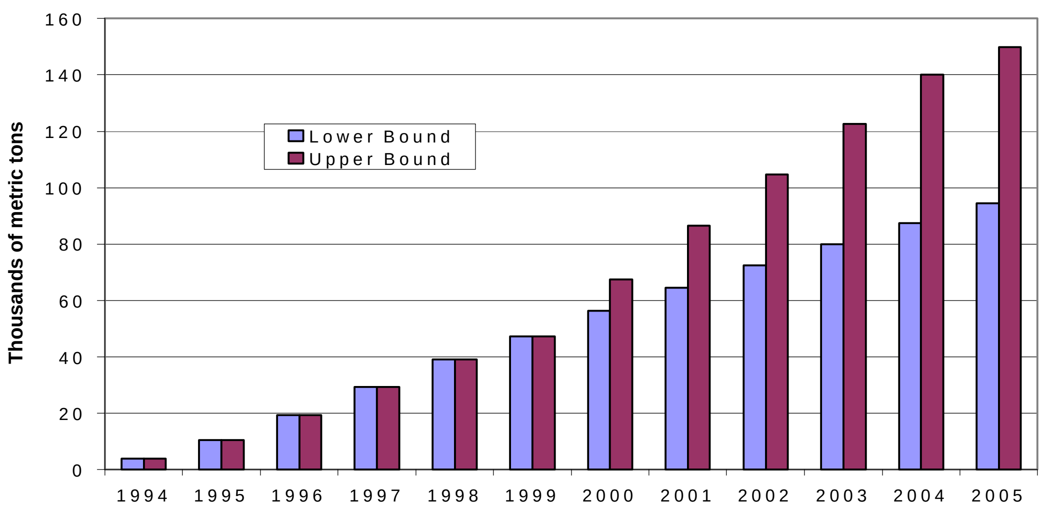


FIGURE 2B: ESTIMATED ON-ROAD VEHICLE CO EMISSION REDUCTIONS FROM CMAQ

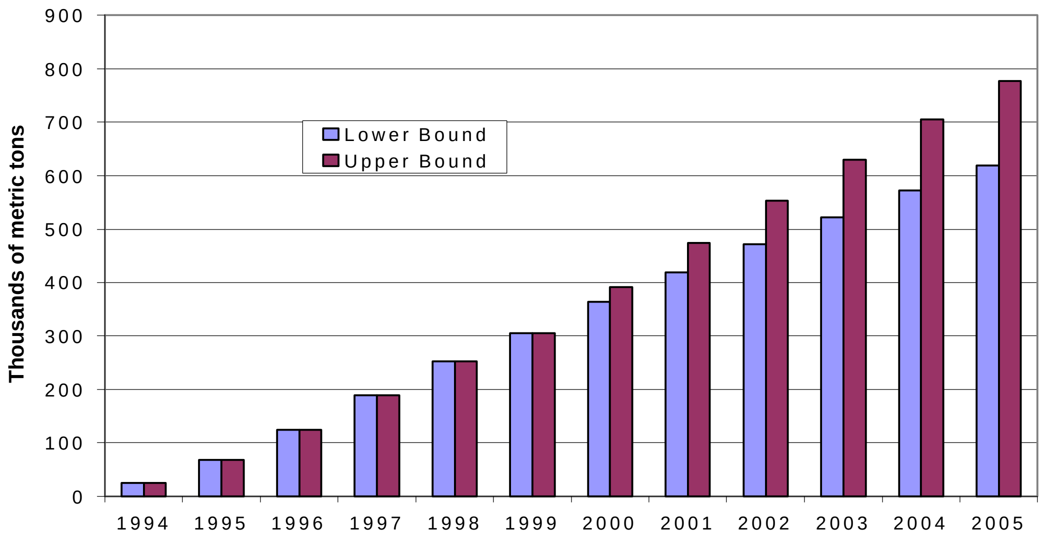


FIGURE 2C: ESTIMATED ON-ROAD VEHICLE NO_X EMISSION REDUCTIONS FROM CMAQ

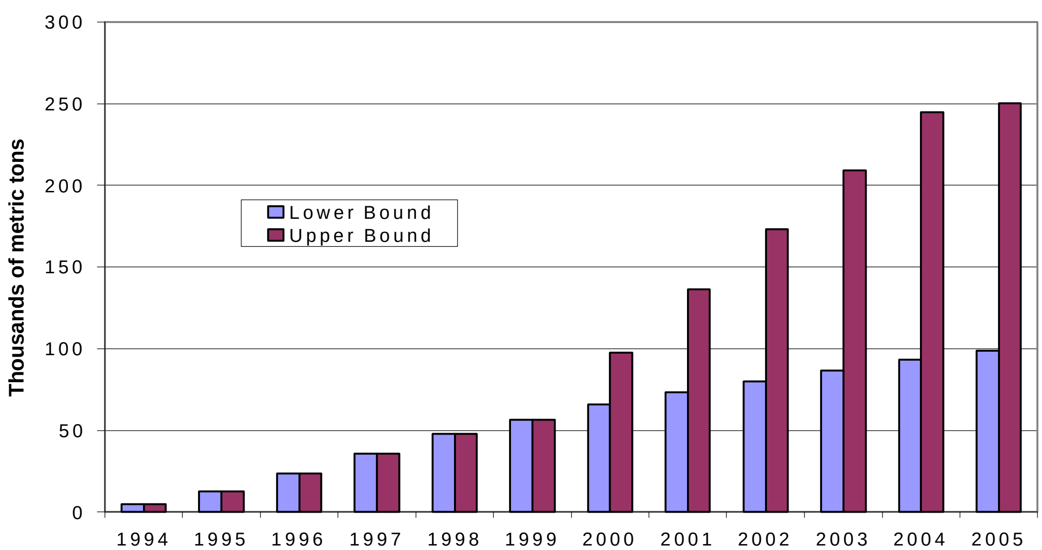
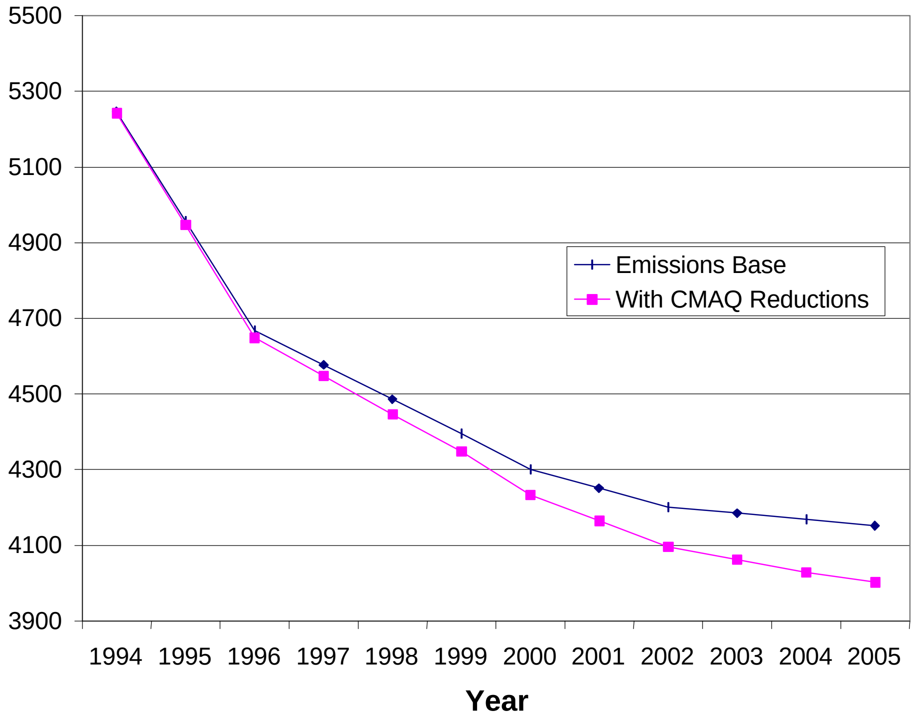


FIGURE 3: ESTIMATED VOC EMISSION TRENDS FROM ON-ROAD VEHICLES



TABLES

FIGURES